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Procedia Technology 3 (2012) 259 – 266

Procedia Technology

The 2012 Iberoamerican Conference on Electronics Engineering and Computer Science

Incorporating three dimensional sound in Virtual Environments

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Abstract

This paper focuses on the behavior of sound on combining: "Navigation, 3D objects and 3D sound", in different virtual worlds, which are displayed on multiple screens. Our project allows building different virtual environment using one or more screens, with a full navigation system, four ways of manipulating using keyboard, head tracker, remote control and input files with different predefined tours. Furthermore, with this project we can also build a Wheatstone- type stereoscope.

We have implemented three virtual worlds for the different environments: The first one shows a collection of anaglyphic photographs; the second one is a collection of photographs of roman art; the third one is a computing center.

Keywords: 3D sound; virtual environments; inmmersion

1. Introduction

The technological evolution has resulted in a series of benefits to the Virtual Reality area. Now it is possible to build interactive virtual environments where visual, haptic and audible aspects are combined, allowing for the improvement of the simulations.

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doi:10.1016/j.protcy.2012.03.028

We are surrounded by a lot of sound sources in our daily life, which are produced by different objects, many of these sounds are easy to recognize due to our familiarity with them. Therefore, when it is included in a virtual world undoubtedly improves the realism. The type of sound depends on the virtual world.

Different authors present the incorporation of 3D Sound in virtual environments, such as [1], [2] and [3]. [1] applies the concept of interactive hyperstories to blind children. Hyperstories are tried out in a 3D acoustic virtual world. [2] uses one sound source changing its position for evaluating the improvement of the location of sound using dynamic movement of the human head. [3] describes a virtual assembly environment, in this work the authors carry out an evaluation and a comparison of the use of isolated and combined visual and auditory sense. This project has some similarity to our work, because we integrate the same senses: visual and auditory, nevertheless, [3] focuses on a specific environment and our project uses the 3D sound in different virtual worlds.

Our work presents three different virtual worlds. The first and the second are art galleries with one sound source respectively (background music); and the third is a computing center with nine sound sources and spoken explanations. In these virtual environments the sound sources are used as feedback to some activities, to locate 3D objects, and as background music, all of them were tested in different physical environments.

2. Three Dimensional Sound as an Immersive tool in a Virtual World

Sound is a useful tool that has many advantages. Fundamentally, sound serves as feedback to some actions and results in better immersion. Even music helps to manipulate user's emotions, including happiness, sadness, nostalgia, peace, etc. The use of sound is mentioned in many references focused on the Human-Computer Interaction topic.

3D sound means that a listener hears sounds from any direction; this sound is generally simulated by a computer. 3D sound has many characteristics that can provide advantages in virtual environments. In this work 3D sound has been incorporated due to the following characteristics [4]:

- 3D Sound provides extra help for the user to find objects when he is navigating, because the hearing system can determine the location of the sound sources.
- The 3D Sound produces a high immersion level in a virtual environment.
- The 3D Sound helps to interpret distances among objects.
- The 3D Sound facilitates a more natural interaction because it is similar to the sound in the real world.
- Sound can provide additional information to a graphic world, by helping users to understand extra information without extra effort.

3. Manipulation and navigation of a Virtual world using 3D Sound

3D sound is similar to 3D graphics; it uses the positions of the sound sources, besides the listener orientation and position for creating a real effect. The rotations that the listener is permitted to make are called Elevation and Azimuth. See Fig. 1, Elevation is the angle along the vertical plane. Azimuth is the angle along the horizontal plane. With these rotations user is able to see a virtual world in its entirety and perceive the sound from the new positions. In this project the elevation and Azimuth rotations are included

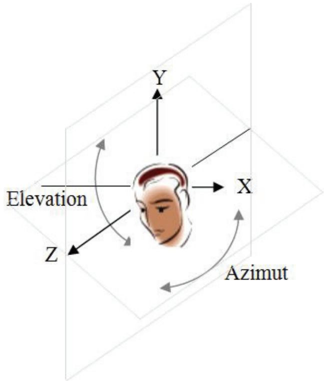


Fig. 1 Elevation and Azimuth Rotations

Three coordinates are used in this work: the positions of the sound sources see Equation (1); the listener position, see Equation (2); and the user orientation with respect to the screens, see Equation (3).

$$SourcePosition_n = x_n y_n z_n \tag{1}$$

where $n \geq 1$

$$LPosition = L_{xyz} \tag{2}$$

$$LOrientation = R_x, R_y \tag{3}$$

The Doppler Effect equation is:

$$f' = DF * f * \left[\frac{v - v_l}{v} \right] \tag{4}$$

With

f	original sound pitch
f '	Doppler effect pitch
v_l	velocity of listener
DF	Doppler factor

Where

$$v = 343.3 m/s \tag{5}$$

4. Project Design

This project has a client-server structure, which allows for the use of a set of devices connected via net, see Fig. 2. A client is a computer, which display part of a virtual world on a screen or monitor. The server manages one or more clients (screens), it obtains the screen configurations, updates the viewer position through an input device, which can be a keyboard, a remote control or a head-tracker.

Each client knows different information as its real position and its size (screen). The client establishes communication with the server via messages. Then the client sends its screen configuration to the server, and the server returns the information necessary to determine the section of the world that corresponds to the display.

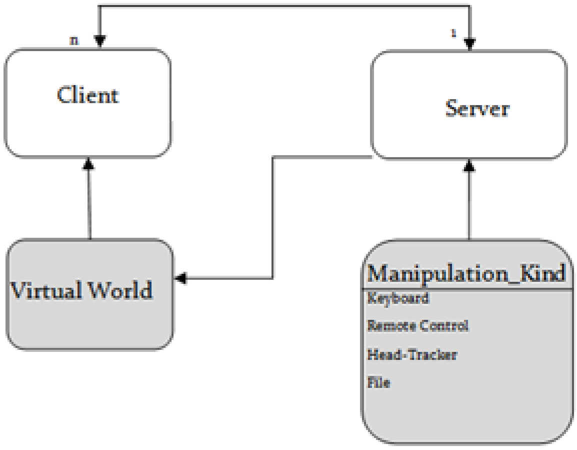


Fig. 2 General Scheme

5. Incorporating 3D Sound into different Virtual Worlds

Each virtual world has a set of objects with at least one sound source. The first virtual world is a gallery, which shows a collection of photographs of roman art, see Fig. 3. This kind of world does not require the use of many sound sources, therefore this gallery only contains one sound source: a loudspeaker placed on the ceiling that plays soft music. When the listener changes his position, it is possible to locate the loudspeaker position.

Fig. 3 Gallery of photographs of roman art

The second world is an anaglyphic gallery. This gallery shows a collection of anaglyphic photographs, this implies that 3D sound, 3D objects and stereoscopy are involved in the same world, see Fig. 4. As the previous virtual world, this gallery does not require many sound sources and therefore it only contains a loudspeaker placed on the ceiling. The spatial effect is perceived when the virtual world is navigated and the sound is heard from the loudspeaker.

Fig. 4 Anaglyphic gallery

The third virtual world that was programmed is a computing center containing nine computers, each one with a sound source, see Fig. 5. In this case, the 3D sound provides the user with some complementary information about the world. Each computer speaks out using a pre-recorded sound clip, specifying details about a planet of the Solar System. As our project is dynamic, when the user navigates through the virtual world, the sounds change too according to the movement made [4].

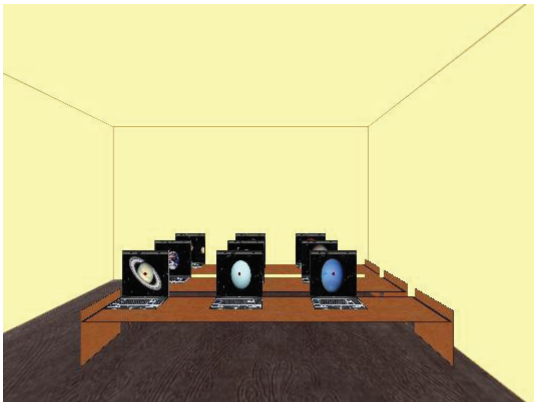


Fig. 5 Computing center with nine computers, each computer has its sound source in red color.

In Fig. 6 the first view is the frontal, two laptops are shown. One of them shows the planet Earth and the other one shows Jupiter. Therefore, the explanation heard about Earth is emitted from the left side of the virtual world and about Jupiter from the right side. If the same laptops are seen from back, see Figure 6, the explanations would be listened to from reverse sides; that is, now the explanation about Jupiter will be emitted from the left side and, about Earth, from the right side.

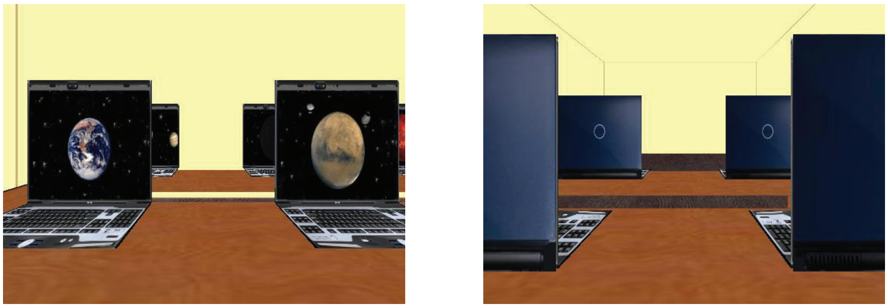
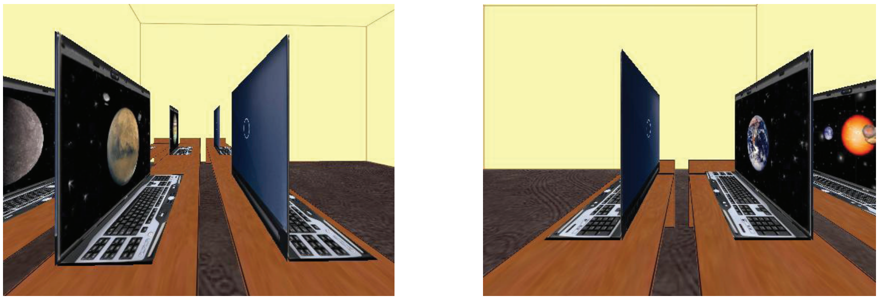


Fig. 6. (a) Frontal view, (b) posterior view

In Fig. 7, the first view shows two nearby laptops. The first one shows Jupiter; the other one shows the posterior side of a Laptop (Neptune). When this scene is seen, the explanation about Jupiter is heard on the left side and about Neptune on the right side. In the second view a rotation of 180^{o} is done and an approaching to two computers. The posterior side of a Laptop (Uranus) is shown as well as the Laptop of Earth and explanations of the planets are heard. The explanation of Uranus is heard from the left side and of Earth is heard from the right side.



¶Fig. 7 (a) Right view, (b) Left view

6. Problems and solutions on incorporating Sound

Different problems were presented when sound was included in this project. They are mentioned in the following points [5]:

- When different sound sources are used in a virtual world, we should have taken some precautions when placing them. If sound sources are placed near each other it can result in interference and confusion between sounds. However, it also depends on the kind of sound. Music and some other sound source do not have problems, but when the sound is a spoken explanation; they can be mixed and therefore not understood, resulting an annoying noise. This problem was found in the computing center, see Fig. 5, since the size of this virtual world is small and the computers are near, the difference in the sound volume between computers was minimum resulting interference and confusion between dialogues. Therefore an adjustment in the volume of the objects was made, limiting the maximum volume reached in the virtual world. The volume of each object (in this case each computer) is V_{obj} and was adjusted with the following equation:

$$V_{obj} = 1 - \frac{d_{obj}}{d_{\max}} \qquad (6)$$

Where d_{obj} is the distance between the viewer position and the object position, d_{max} is the reached maximum distance to hear an object and to avoid interference.

- Every virtual world shown in this document can be used with any virtual environment built with one or more screens. Due to the fact that every environment can display virtual worlds without any modification, this project did not experience any problem when the sound units were included in them.
  This was true except with the Wheatstone-type digital stereoscope, it produces a laterally inverted virtual world [4]. This stereoscope can be built with two monitors or projectors set one in front the other one and a pair of mirrors set in the middle of two monitors, see Fig. 8. When the viewer eyes are set in front of the mirrors the virtual world is seen stereoscopically. If the 3D sound is not used, there is no problem seeing the inverted virtual world. When spatial sound was incorporated we had to invert the world beforehand so that it could be seen correctly and coincide with the sounds.

Fig. 8 Wheatstone-type digital stereoscope

7. Evaluation

The project was tested by 20 users. 95% of the users considered an important improvement on using 3D sound in the different virtual worlds. 95% of the users could perceive that the sound sources were emitted from different 3D objects and notice an improvement in the location of 3D objects when the sound sources were incorporated. All the users considered that the sound can be used as feedback and provides extra information

8. Conclusion

This paper incorporated the use of 3D sound in the building of virtual environments as a complementary tool, because 3D sound allows for the provision of additional information in a graphic world, for instance spatial information such as directions and positions, in addition some explanations, etc. 3D sound allows for having a better interface, which provides realism that other techniques cannot produce.

In this paper a description about how to combine 3D objects and sound sources was described. Additionally, the combining of 3D sound and navigation was discussed, along with the effects produced by such combination.

The 3D sound in our project was specifically used in two ways:

- As supplement to visual information through: Spatial Information and Spoken explanation

- As background sound in two galleries of art.

The incorporation of 3D sound was done in three virtual worlds; they were shown and tested in this chapter. When 3D sound was incorporated in the worlds two problems were found:

- When different sound sources are placed near each other it produces interference and confusion between sounds. Therefore an adjustment in the volume of the objects was made, limiting the maximum volume reached in the virtual world. The solution was the volume adjustment of each object using the Eq. 6. In this equation the maximum distance to hear an object is limited.
- The second problem was detected on incorporating 3D sound in the Wheatstone-type digital stereoscope, because it produces a laterally inverted virtual world, the solution was to invert the world beforehand so that it could be seen correctly and coincide with the sounds.

Acknowledgements

This research project would not have been possible without the support of PROMEP (Programa de Mejoramiento del Profesorado)

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